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Special Report 81

CORING OF FROZEN GROUND BARROW, ALASKA

SPRING 1964

JULY 1965

U.S. ARMY MATERIEL COMMAND
COLD REGIONS RESEARCH & ENGINEERING LABORATORY
HANOVER, NEW HAMPSHIRE

DA Task IV014501B52A31

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by

Paul V. Sellmann
and
Jerry Brown

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PREFACE

This program was conducted under U. S. Army Cold Regions Research and Engineering Laboratory (USA CRREL) Project 3.3B, Frozen Ground Investigation, Barrow, Alaska. Although the coring program has been discussed over the past three years, the final decision to implement the program for spring 1964 was not made by project personnel until late November 1963. By 1 March 1964 all necessary equipment had been readied and phased in Fairbanks for movement to Barrow. During this short three-month period the Alaska Field Station of USA CRREL overhauled and mounted on trailers the drill and compressor, and the Logistics and Supply Branch procured and shipped a considerable quantity of equipment from Hanover, N. H. The authors gratefully acknowledge this support, without which the project could not have been accomplished. Arctic Research Laboratory is similarly acknowledged for their unlimited support while at Barrow. The authors wish to thank Ian Lange for his enthusiasm and highly capable assistance during the coring program. This report was originally issued as an unedited operational report in June 1964.

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CORING OF FROZEN GROUND, BARROW, ALASKA, SPRING 1964

by

Paul V. Sellmann and Jerry Brown

OBJECTIVES OF THE INVESTIGATION

The triangular-shaped land mass of the Barrow peninsula constitutes the northern extremity of the Arctic Coastal Plain. The near-surface sediments of the Gubik formation are a reflection of late Pleistocene events and therefore contain a valuable record of sea-level fluctuations and climatic changes. Continued investigations in Pleistocene stratigraphy along the northern coast of Alaska will provide additional information for regional and world-wide correlation of Pleistocene and recent events. Cliff exposures in the immediate Barrow area do not provide adequate sections for detailed sampling. Consequently, a coring program was chosen as an appropriate means of acquiring the desired data.

Although the major objective of the coring program is to provide additional detailed sampling and analyses for late Pleistocene stratigraphy, several other objectives are considered important:

(1) To ascertain the boundary between the reworked sediment and the underlying undisturbed sediments. The near-surface sediments are reworked by migrating lakes and by cryopedologic processes including frost churning and growth of ice wedges. It is essential to know at any one location the depth to which these surface disturbances of sediment have occurred for geological, pedological and engineering purposes. Sampling of the near-surface material in the upper 6 meters had been accomplished earlier by use of auger holes.

(2) To ascertain moisture-depth relationships on representative geomorphic units. Distribution of ground ice varies from one type of surface to another, as well as within discrete terrain units. It is important for engineering criteria to determine this vertical and areal variation in ground ice. The data are also essential for calculation of ground volume and sea level changes. This subsurface information will be applied to aerial photographs and extrapolated to other nearby coastal areas.

FIELD METHODS

Sampling

To accomplish these objectives it was necessary to initiate a detailed coring program. Since the coring was programmed for the spring, when snow cover is at a maximum, it was necessary to select potential sites during the snow-free period in 1963. In conjunction with other programs approximately 700 locations were selected and staked in the area north of 71°15'. The sampling, however, was mainly confined to a strip across the Barrow peninsula which had been sampled in 1962 and 1963 to depths of 6 m by use of a highway auger. Sites were selected to avoid ice wedges and were generally in the centers of polygons. Figure 1 is a map indicating the location of each hole. There are six other holes in the vicinity of 26B at 100-m spacings.

One requirement for the sampling was that the cores be as nearly uncontaminated chemically as possible. For this reason, conventional fluids were not used for chip removal. Instead, naturally refrigerated compressed air was employed. No attempt was made to keep the core thermally undisturbed during coring or in storage. In addition, it was required that the entire drilling operation be extremely mobile with maximum set up time at each location of less than 1 hour.

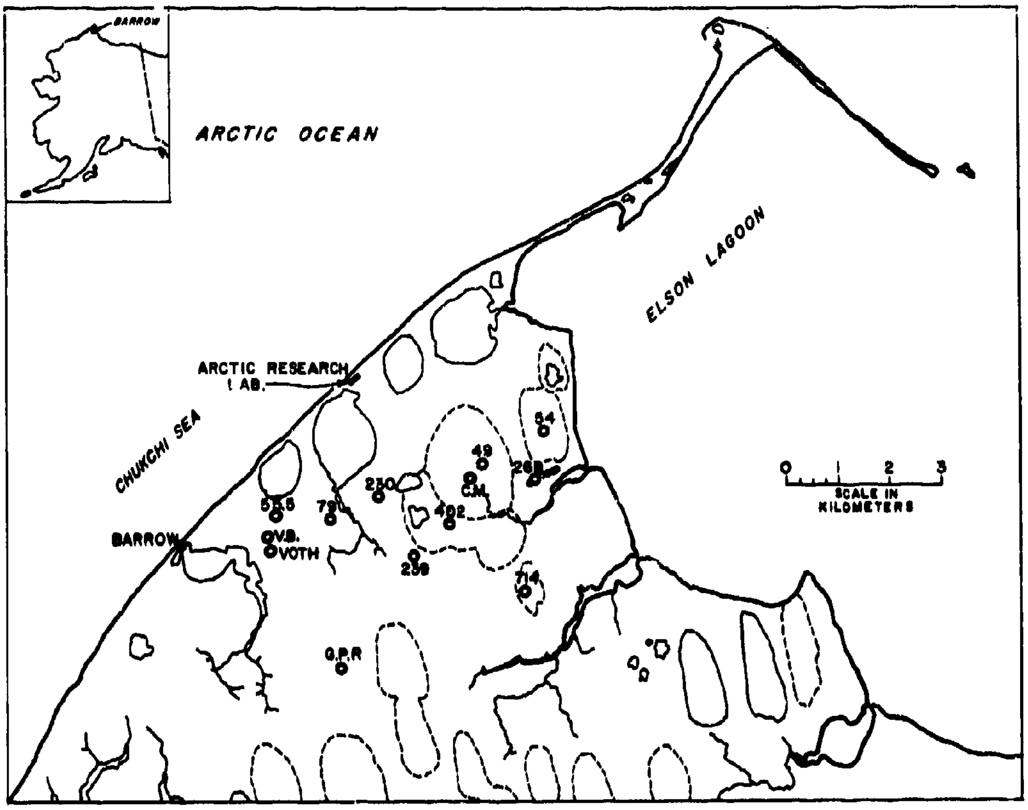

Figure 1. Map of the Barrow area indicating the locations of sample sites, spring 1964.

Equipment, operation and performance

The field season began on 5 March with arrival of equipment at Barrow and terminated approximately 15 May 1964. The following major pieces of equipment were employed:

a) Failing 43-SA rotary type drill rig
b) 210 CFM compressor
c) D-4 tractor
d) 450,000 BTU/hr space heater
e) 2 Cargo carriers (weasels)

Figure 2 illustrates the assemblage of equipment at a typical drilling site.

Drill. The rotary type, gas-driven drill (Failing 43-SA) was mounted on a Model M, Muskeg tracked trailer. The entire trailer was enclosed by a wooden house so that drilling could proceed under any weather conditions. The total weight of the trailer, drill, and house was approximately 3 tons. The drill performed well during 270 hours of operation. There was less than 20 hr of down-time due to mechanical failure, none of which rendered the equipment completely inoperative. The drill started without heating at temperatures as low as -35C. Figure 3 shows the drill in position for deep coring.

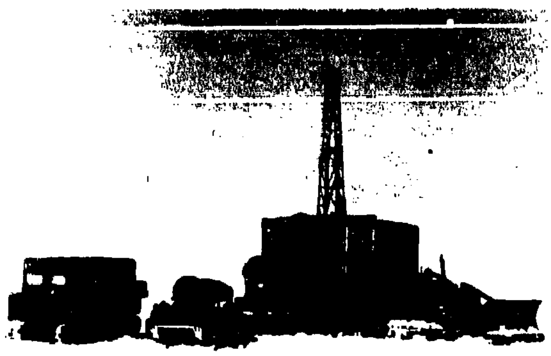

Figure 2. A typical drilling setup about 4 kilometers from Barrow. Equipment from left to right: weasel, heater, compressor, drill rig, and tractor.

Figure 3. Failing 43 drill in position for deep coring. Note air-discharged cuttings blanketing the snow surface.

Air compressor. A gas-operated, piston type, 210 CFM compressor was mounted on a Model T-7 Muskeg trailer. No additional housing was required. There was negligible down-time during the 270 hr plus of operation. The compressor required at least 45 min of preheating before starting at temperatures between -15 and -35C.

Heater. A 450,000 BTU/hr diesel-operated space heater was mounted on a 1-ton, weasel-drawn sled. The heater required a 110-volt power source which was provided by a 2 cycle, 1.5-kw generator. Fuel consumption of the heater was 1.5 gal/hr.

Traxcavator. A modified D-4 tractor equipped with a blade and special sand tracks was used to move the trailer-mounted drill and compressor. During the months of March and April when the snow was still hard, it was possible to pull both the drill and compressor at the same time. In May when the snow softened, it became necessary to pull them separately, thereby lengthening the time of movement between locations. The tractor operated well with routine maintenance performed as prescribed. It was usually stored in a heated building at night; otherwise preheating was required before it would start.

Weasels. Two cargo carriers, M-29 Army weasels, were used to transport light equipment, fuel and personnel from the Arctic Research Laboratory to the field sites and return. They required weekly lubrication, recommended servicing, and an occasional tune-up. The only actual mechanical failure was a broken track, which was replaced. In the period 5 March to 1 June the two vehicles logged better than 2100 km (1300 miles).

Drilling accessories and techniques

Two different types of core barrels were utilized. A standard, double tube, large series, swivel type, $2\frac{3}{4} \times 3\frac{7}{8}$-in. core barrel was used for all of the subsurface coring. A single-wall, concrete-type core barrel equipped with a commercial tungsten-carbide bit (Wyr-lok) was employed for obtaining samples in the upper meter of soil. This hole, after reaming, served as a starter hole for the longer core barrel.

The material sampled consisted of the Gubik formation, a Pleistocene to recent marine and nonmarine deposit composed predominantly of sands, silts and gravels. The near-surface sections consist of large quantities of segregated ground ice, massive wedge ice, and organic materials in the mineral sediment. Even though the sediments are unconsolidated they are indurated by ice to form a material with drillability often approximating that of concrete. The bit must operate efficiently enough so that only small amounts of heat are generated in the cutting process; otherwise melting would eventually cause clogging of the bit and outer annulus. A bit that penetrates by abrasion will not work since a milling action is required. Sufficient quantities of cold air are necessary to cool the cutting surface and remove the chips from the hole.

Casing of the hole is not generally necessary in the upper 20 to 30 m of this sediment due to the frozen condition of the sediment. Casing is required in zones of brine-saturated sediments and in unconsolidated units low in moisture such as gravels and coarse sands. Although no casing was employed in this operation, only once was drilling terminated because of collapse due to brine saturation.

The bits for the double-walled core barrel were designed and made by the senior author. The basic design was a drag bit, saw-toothed arrangement with either five or six teeth. Tungsten-carbide inserts were silver soldered into place with the rack and pitch of the cutters varied experimentally. The grade of carbide found most satisfactory was Adamas Carbide 569. The best performance was obtained with the six-tooth bit illustrated in Figure 4.

Each bit would cut a minimum of 1.2 m of sediment before requiring sharpening. The bits were sharpened daily by hand on a conventional $\frac{3}{4}$-hp grinder using a Norton, soft silica carbide, grinding wheel.

Penetration rates were controlled largely by the amount of moisture (ice) and the grain size of the material. The best penetration for recovered core was in sandy silt having a moisture content of approximately 20%, with a rate of about 30 cm/min. Recovery of massive ice was possible, but more difficult. High-ice sediment required lower penetration rates for good recovery. The slowest penetration rates averaged 3 cm/min in silt having moisture contents between 30 and 40%.

Figure 4. Tungsten-carbide tipped, saw-tooth, internal discharge bit ($2\frac{3}{4}$ x $3\frac{7}{8}$ in.). This combination proved most successful in coring frozen sediment.

Under all conditions of coring low rpm produced the best results. This minimized wearing of the bits, reduced bit damage due to impact when gravel was encountered, and maintained a low temperature at the drill bit-sediment interface. Optimum operating rpm was from 70 to 120 with drilling pressures between 40 and 60 psi.

Chip removal using naturally refrigerated, compressed air was no problem with air temperatures below -6C. At ambient temperatures of -33C compressional warming brought the temperature of air discharged from the storage tank up to +10C. The air was cooled to -12C by passing it through 15 m of pressure hose and circulating it directly into the swivel. As ambient temperatures warmed it was necessary to add an additional 30 m of hose and an after-cooler constructed of 10 m of finned radiator pipe. When ambients rose above -6C coring with naturally refrigerated, compressed air was no longer feasible.

Table I indicates the depth of each hole and the amount of core recovered. On only about one-half the sites a starter hole was drilled to approximately 75-cm depth before using the longer, double-wall core barrel. Therefore, at some sites no core was recovered in the upper $\frac{3}{4}$ m. Disregarding this surface loss core recovery was approximately 98%. Greatest loss was in gravel and loose sand, although core could be recovered in ice-cemented gravel. Figure 5 is a photo of a section of core.

SAMPLE PROCESSING

The frozen cores were placed in flexible polyethylene tubing immediately upon removal from the core barrel. The cores were transported to the ARL cold room and stored. At the end of each coring week, the cores were photographed and logged. The core was then placed in 1.5-m sections of rigid clear plastic tubes and capped on both ends. The inside diameter of the tubing very closely approximated the core diameter. The cores were stored in these tubes until all coring and logging was completed and a preliminary correlation made.

The cores were then sampled for a variety of analyses. For overall correlation, individual sedimentary units were sampled, generally at approximately 0.5-m intervals. This sampling was accomplished by cutting the core with a tungsten-carbide, circular saw blade in a conventional table saw. A 5 cm long segment of core was oven-dried and moisture content determined. This oven-dried sample is later used for grain-size analysis and paleontological examination. A second sample approximately 10 cm long, taken adjacent to the first, was placed in a plastic bag, thawed, and returned to the USA CRREL laboratory at Hanover, New Hampshire, for chemical analysis. In

Table I. Record of 1964 coring, Barrow, Alaska.

Location designation	Total depth (m)	Core recovery (m)
54	17.0	16.1*
714	15.0	15.0
49	16.3	15.4*
CM	7.3	6.4*
402	13.4	12.5*
239	14.6	14.0*
230	12.3	11.6*
79	13.5	12.7*
55.5	18.9	18.2*
V. B.	8.7	8.0*
Voth	11.2	9.7*
GPR	7.0	2.2*
16B	3.7	3.7
18B	3.6	3.6
20B	4.2	4.2
22B	4.5	4.5
24B	4.5	4.5
26B	20.8	20.8
27.5B	5.6	5.6
Misc soil samples	10.5	10.5
Total	212.6	199.2

Recovery of total attempted core -97.9%

Recovery including surface 0.7 - 0.8 m -93.7%

*Surface $\frac{3}{4}$ m not sampled

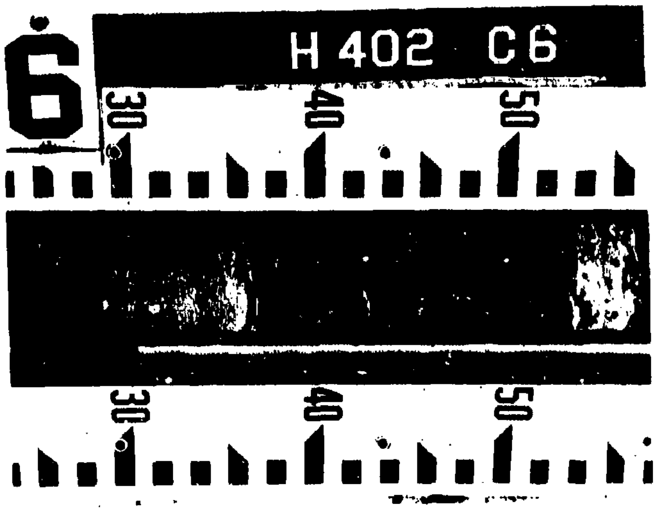

Figure 5. Selected section of frozen core illustrating interbedded sands and silts. Scale is in centimeters.

some instances where samples were above saturation, the water was extracted by use of a vacuum funnel and the electrical conductivity of the extract determined at Barrow. More detailed chemical and moisture analyses were conducted on cores from the B sampling (26B), the Voth and V. B. holes, and the miscellaneous surface soil samples.

The unused frozen core was returned to the rigid plastic tubes, recapped and placed in the underground meat cellar at the Barrow camp for future examination.

COST OF OPERATION

It is difficult to estimate cost of operation at Barrow for such a project. A great deal of equipment, tools, and supplies came from both Hanover and the Alaska Field Station of USA CRREL. The following figure includes cost of room, board, and clothing for 6 man months at Barrow which were provided by ARL at no additional cost to USA CRREL; fuel and maintenance of weasels at Barrow and construction by ARL of a house on the drill which were also provided at no cost to CRREL; overhauling and mounting of the drill and compressor at Fairbanks; purchase of a heater, trailer, rigid plastic core containers, drilling accessories, and parts; air-lift of heavy equipment to Barrow and other freight; salaries for 6 man months; and transportation of personnel from Hanover to Barrow and return. The maximum cost including all the above items is $115/meter ($35/ft) based on the recovery of approximately 200 m of core. This value agrees favorably with costs in Fairbanks. The cost of the operation was minimized by operating with a two-man crew, both of whom were geologists (Sellmann and Lange).

The operational expenses at Barrow, minus salaries, were paid by the Arctic Research Laboratory operated by the University of Alaska under contract with the Office of Naval Research. The unlimited facilities available both through ARL and the Barrow camp reduced the cost to USA CRREL considerably. Such an operation at more than one day's ground travel from Barrow would greatly increase the cost of a mobile drilling operation, since hour-to-hour necessities would not be available unless preplanned and purchased in advance.

PRELIMINARY OBSERVATIONS

From the preliminary field description of the cores it is possible to make several generalizations concerning the potential outcome of the coring program. It appears that sedimentary units to depths of some 20 m can be accurately correlated over distances of 4 km or more. Much of the Barrow sediments were deposited in near-shore environments with high order variations in depositional energy levels. These changes vary from clean sand and gravel to dark organic rich silts. An elevated ridge, previously reported as a beach ridge, was found to be underlain by a considerable thickness of ice-cemented gravel and coarse sand. Highly fossiliferous zones are common in most cores and will serve as excellent means of correlation with previously described sections from the Northern Coastal Plain of Alaska. In general, it appears that primary sedimentary structures are preserved below 7 m, while in drained lake basins which have not been intensively dissected by ice-wedge polygons, the maximum zone of disturbance is less. Organic materials recovered from several cores yielded radiocarbon dates in excess of 25,000 years B. P.

The detailed shallow coring at every 100 m in the vicinity of hole 26B revealed several strata that occurred in each hole at approximately sea level. These subsurface markers will facilitate accurate computations of ground volumes, ice contents, and chemical gradients, as well as aid interpretation of the history of the local area.

Moisture contents of the sediment decrease with depth, the major decrease being around 6 to 7 m in areas of abundant ground ice. Below these depths moisture contents fluctuate slightly and are generally between 15 and 25%.

Brine-saturated sediments were encountered at only one location (Voth) below a topographic high. This occurrence will undoubtedly prove exceedingly significant in

the final interpretation of the development of frozen ground in the Barrow area. Three holes, 20.8 m, 18.9 m and 17.0 m deep, although within 2 km of the ocean or lagoon sediment, were not brine-saturated at the bottom.

Intensive examination and analyses of selected samples and further reduction of the data promise to supply pertinent information towards answering the objectives of this program. The solution of the stratigraphic problems will utilize statistical sedimentation techniques. Additional reports on these studies will be forthcoming as the work progresses.

SUPPLEMENTARY

INFORMATION

NOTICES OF CHANGES IN CLASSIFICATION, DISTRIBUTION AND AVAILABILITY

69-20 15 October 1969

IDENTIFICATION	FORMER STATEMENT	NEW STATEMENT	AUTHORITY
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